FINAL REPORT FOR ONR AWARD N00014-96-1-1176

Title: Spectral Upwelling Radiance and Irradiance Measurements
Made During TARFOX on the CIRPAS Aircraft.

By John N. Porter

During the June 1996, the Tropospheric Aerosol Radiative Forcing Observational Experiment (TARFOX) was carried out at Wallops island. The goal was to measure both the aerosol characteristics and their radiative forcing. In support of this effort, we mounted two spectrometers on the Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS) Pelican aircraft. One spectrometer measured the upwelling radiance over a narrow field of view. The second spectrometer measured the upwelling irradiance with a cosine response collector. The two spectrometers worked very well during the experiment and a valuable data set has been collected on eight flights which can be used to test and further develop aerosol radiative models.

The spectrometers ranged measured light from 300 to 1130 nm but due to their spectral response, useful measurements can only be collected from 375 to 1050nm. For the TARFOX experiment, our computer software was configured to sample the two spectrometers sequentially. Each spectrometer had autoscaling of the integration time from 10 to 530 msec. This autoscaling process maintained good signal to noise over a broad range of radiance values by maximizing the spectrometer counts while avoiding saturation. Converting from one integration time to another time took less than one second. Radiometric calibration has a high priority and many hours have been spent on this issue. During TARFOX, we had the opportunity to calibrate our system with the UK lamp and reflectance plate system thanks to John Taylor, Ian Rule and Jim Crawford. This provided our first calibration standard. Following the experiment, we carried out calibration tests with a Labsphere integrating sphere (courtesy of Paul Lucey, University of Hawaii) and Optronics integrating sphere (courtesy of Dennis Clarke, Marine Optical Buoy, (MOBY), Hawaii). Both of these systems were calibrated by Optronics and are NIST (National Institute of Standards and Technology) traceable standards. For our final calibration, the three calibrations were averaged and is shown in Figure1. It can be seen that the counts per radiance are quite high providing good signal to noise over much of the spectrum. Above 950 nm the spectrometer sensitivity drops off. Based on the uncertainties provided by Optronics and the variability in our

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13. ABSTRACT (Maximum 200 words)
Upwelling radiance measurements were made on the Cirpas aircraft during the TARFOX experiment. Measurements were made from .375 to 1050nm wavelengths.

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comparisons, the uncertainty in our spectrometer calibration is expected to be ±5% above 500nm and near 7% below that.

Prior to the experiment the sensors were mounted on the aircraft while at Monterey, California. At that time Paul Finn helped to devise a mechanical shutter system which allowed the pilots to periodically perform zero test on spectrometers. This was needed because the spectrometers were not cooled and the dark counts ranged from three to 30 counts depending primarily on integration time but also on ambient temperature. Comparing the system dark counts (when the shutters were closed in flight) with the spectrometer normal counts it was confirmed that the high end of the spectrometer (above 1120 nm) was essentially counting zero. This is expected due to the poor sensor response above 1050 nm seen in Figure 1. Therefore the counts at these longer wavelengths were used as dark counts under normal operating conditions. When the spectrometer encountered sudden changes in radiance and saturation occurred at certain wavelengths then the spectrum was discarded. In this way the software autoscaling feature was keeping the spectrometer at near constant count levels and the therefore the dark count above 1120 were also near constant. On some occasions (typically over green vegetation) the spectrum changed so dramatically that even the counts above 1120 nm were affected. At these times the dark counts were assumed to be similar to previous dark counts. In doing this dark count corrections, corrections were made to account for the integration time and subsequent tests confirmed the dark counts had a linear response with integration time.

The non-linearity of the system is studied in Figure 2a and 2b while looking into the Labsphere integrating sphere. For this test, the integration time was varied from 10 msec up to 440msec which is near saturation (4095 counts). As seen in Figure 2a, the near saturated values were up to 8% lower than the cases with lower integration times (lower counts). In order too correct for this, the total number of counts were monitored and corrections were applied. The result of this process is shown in Figure 2b resulting in less than 1% difference. Tests prior to the experiment showed the spectrometer had an equivalent width of 8nm and stray light rejection of a least 3.5 orders of magnitude.

Figure 3 shows some of the data collected on day 198. Several wavelengths are shown. Unfortunately, we have not jet obtained the aircraft tilt, pitch, height and position information. Once we receive this information we can be more certain of what we are looking at. Despite this uncertainty, it appears that from hour 18 to 19.2 the aircraft is looping down and up from the surface. The periodic spikes appear to be sun glint reflection and are fairly smooth if the x axis is expanded. These features are similar to those observed during the ACE1 where we were able to use the aircraft attitude information to calculate the sensor azimith and zenith angles as well as the scattering angles. We hope the aircraft attitude information for the Pelican will be available soon. Figure 4 shows the wavelength spectra for one of the spike regions and one of the flat regions just prior to hour 19. We are guessing that at this time, the aircraft is near the surface and that one spectra is looking at the ocean surface in the sunglint direction and the other away from sunglint. As expected, water vapor absorption regions can be seen at 940, 825 and 730 nm. O_2 absorption is occurring at 750nm.

So far we have shown only the radiance data. The irradiance sensor worked well during the experiment and valuable data was collected but we have not been able to calibrate it as of yet. As we learned with the radiance sensor, it is best to not waste time with poor calibration standards. Therefore we will wait until we obtain a new NIST traceable lamp system which we will be obtaining from an NSF ship grant. We are also seeking additional funds to analyze the TARFOX and ACE1 data sets as we believe this data set will be an excellent way to test several new passive remote sensing approaches.

CONCLUSION

A valuable data set of upwelling radiance and irradiance measurements has been collected during the TARFOX. The radiance measurements are radiometrically calibrated and can be made available to the public once we obtain the aircraft attitude information. The irradiance measurements still need to be calibrated and we are awaiting a NIST traceable irradiance source in order to carry out this effort properly. We believe the combined data will provide an excellent way to test and aerosol radiative forcing.

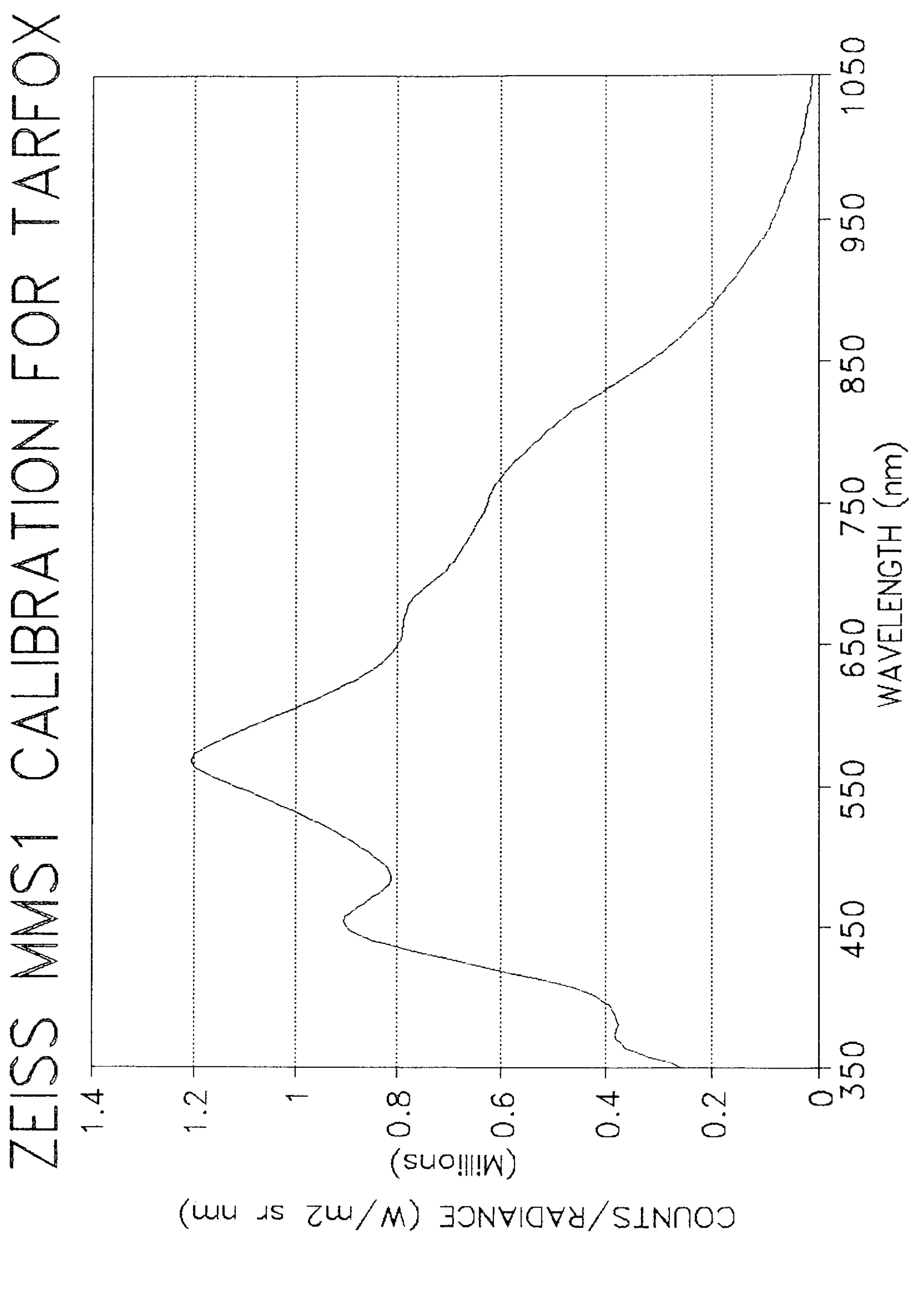
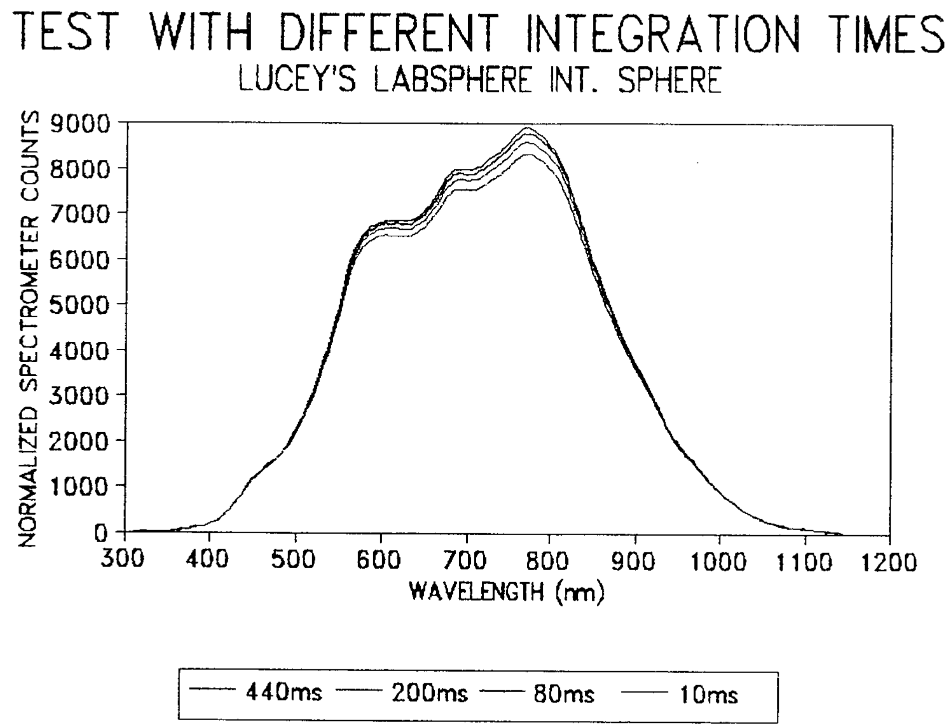

ZEISS MMS1 CALIBRATION FOR TARFOX
COUNTS/RADIANCE (W/m2 sr nm)
(Millions)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
350
450
550
650
750
850
950
1050
WAVELENGTH (nm)

Figure 1


TEST WITH DIFFERENT INTEGRATION TIMES
LUCEY'S LABSPHERE INT. SPHERE
NORMALIZED SPECTROMETER COUNTS
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
300
400
500
600
700
800
900
1000
1100
1200
WAVELENGTH (nm)
440ms
200ms
80ms
10ms

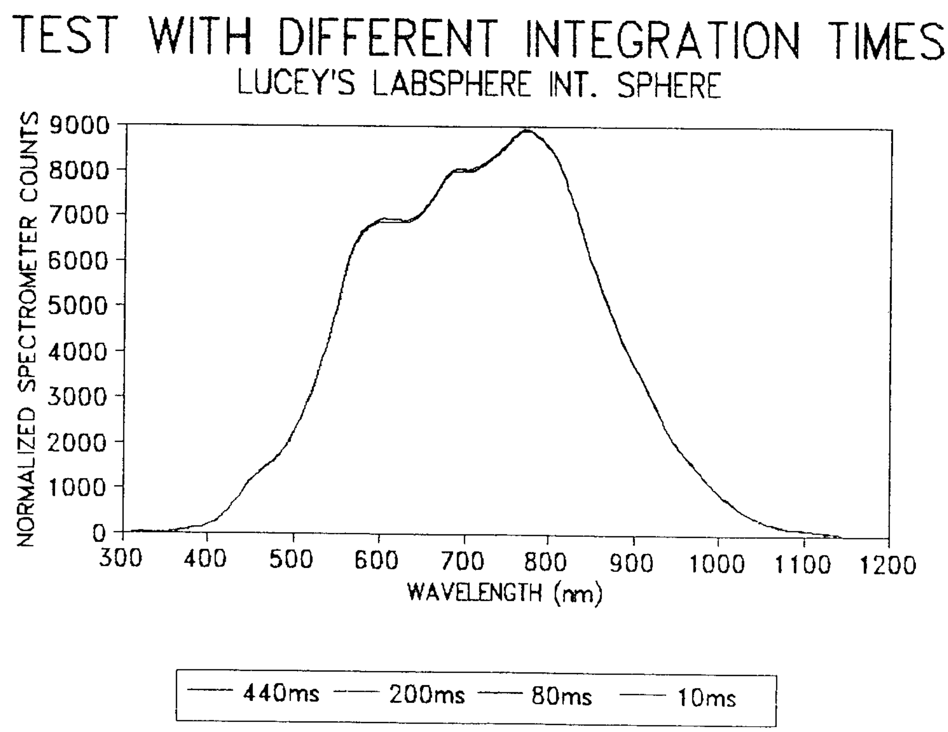

TEST WITH DIFFERENT INTEGRATION TIMES
LUCEY'S LABSPHERE INT. SPHERE
NORMALIZED SPECTROMETER COUNTS
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
300
400
500
600
700
800
900
1000
1100
1200
WAVELENGTH (nm)
440ms
200ms
80ms
10ms

Figure 2

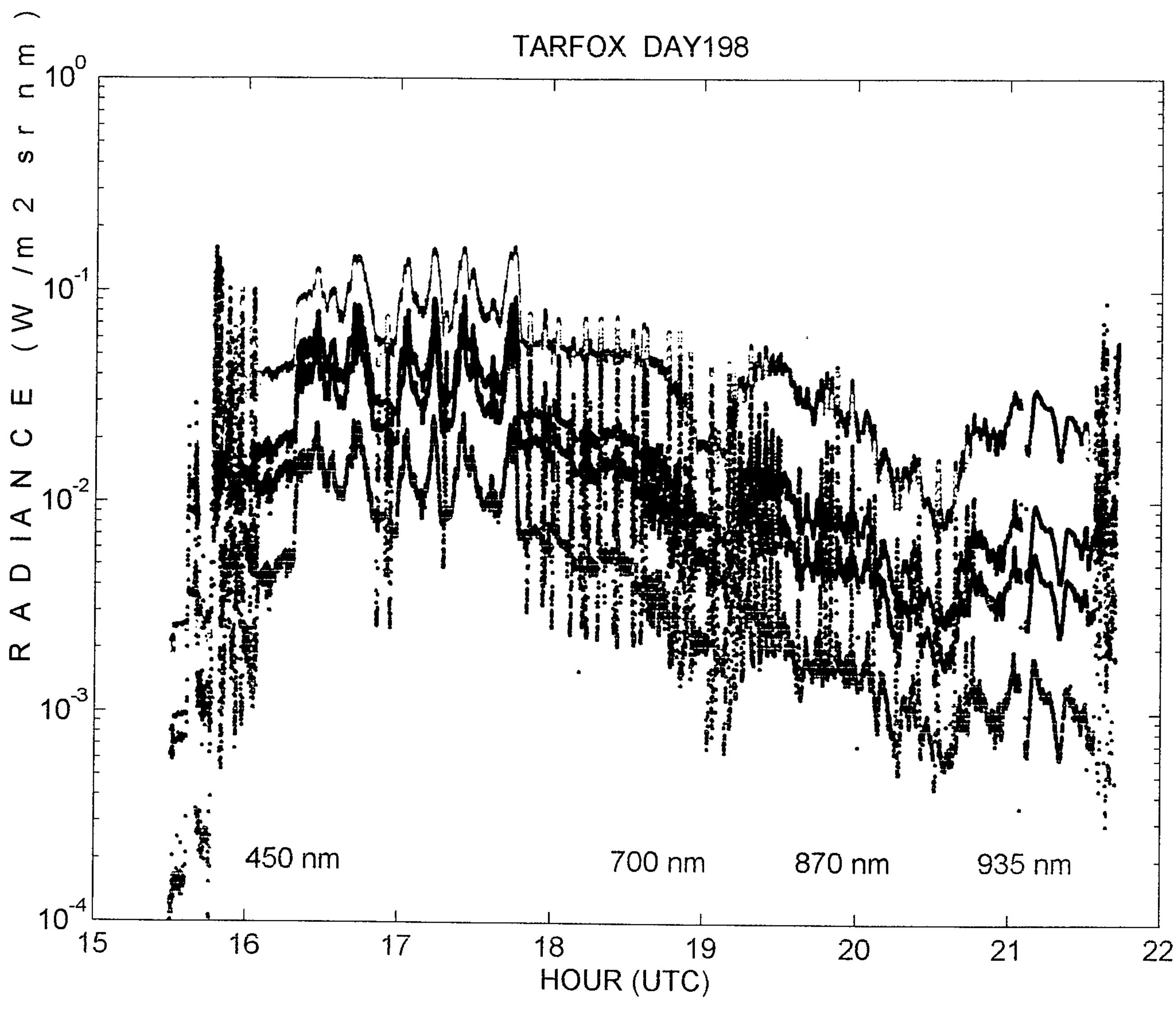

TARFOX DAY198
RADIANCE (W/m2 sr nm)
10^0
10^-1
10^-2
10^-3
10^-4
450 nm
700 nm
870 nm
935 nm
15
16
17
18
19
20
21
22
HOUR (UTC)

Figure 3

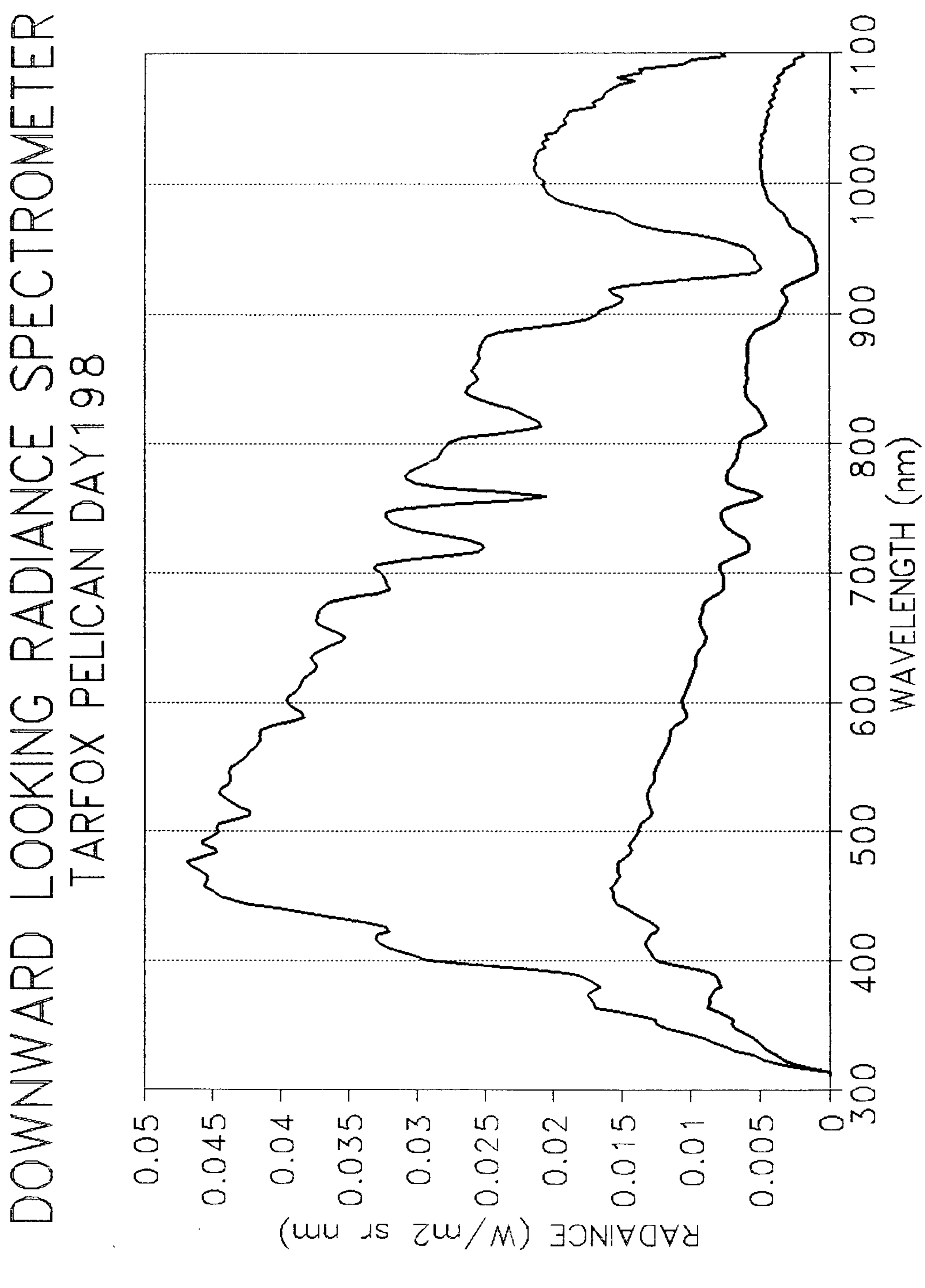

DOWNWARD LOOKING RADIANCE SPECTROMETER
TARFOX PELICAN DAY198
RADAINCE (W/m2 sr nm)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
300
400
500
600
700
800
900
1000
1100
WAVELENGTH (nm)

Figure 4